OPERATIONAL SUITABILITY MODELING AND SIMULATION

An Overview

MARCH 1990

THE OFFICE OF THE DIRECTOR OF OPERATIONAL TEST AND EVALUATION

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Operational Suitability Modeling and Simulation was prepared by the Office of the Director of Operational Test and Evaluation (ODOT&E) to provide an overview of the valuable contributions that Modeling and Simulation (M&S) can make to operational test and evaluation activities. The document discusses the role of operational suitability M&S as well as the structured approach for the use of M&S. The report includes as an appendix, the modeling and simulation systems, environments, and models.

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OPERATIONAL TEST AND EVALUATION

SUBJECT: OPERATIONAL SUITABILITY MODELING AND SIMULATION

Operational suitability modeling and simulation (M&S) should not be viewed as a substitute for field testing. Our primary objective is to acquire maximum operational suitability data from field testing with representative equipment, typical operators, and typical support personnel, in a stressful operational environment.

This report on the application of modeling and simulation to operational suitability as an adjunct to actual testing is important for many reasons:

First, it is published to provide guidance, examples, and reference materials to improve the consistency of M&S application. The report is intended to be a beginning--not an end--and to be a living document that will continue to evolve and provide current and helpful information towards improved operational suitability OT&E.

Second, it represents a clear statement of the importance of operational suitability and the need to highlight and improve its assessment during OT&E. Clearly, the 1980's were the decade of recognition of the importance and impact of operational suitability. This document will help DoD in its quest for greatly improved operational suitability of our weapon systems.

Third, it provides a needed forum--a forum to clarify the proper role of M&S in OT&E. As with any tool, M&S can be misused, even over used. Some basic ground rules are:

- A primary role for operational suitability M&S is the development and analysis of OT&E parameters, hypotheses, and criteria. As a result, there will be a better understanding of the relevance of data collected during test and the criticality of attaining specified operational suitability levels.

- Under closely controlled conditions, operational suitability M&S can provide a structure for assessments that cannot be attained through field testing. For example, the pace and scale of operations during most field tests do not provide an environment for the direct measurement of system operational availability. M&S can provide insights on the impact of test results on these measures.

- DOT&E understands the potential for misuse of M&S and will work with the Oversight Agencies and the Operational Test Agencies to ensure that the application of M&S is properly planned, controlled, and documented and that the models and simulations themselves are properly verified and validated.

In summary, I support and encourage the application of M&S as a valuable tool that can greatly enhance the value of OT&E to the decision makers. At the same time, we must all work together to ensure that our application of M&S will stand the common sense tests of credibility, intelligence, and integrity and that it can never displace the need for actual testing under real operational conditions.

Robert C. Duncan

Robert C. Duncan
Director

FOREWORD

The effective operational test and evaluation (OT&E) of defense systems is a critical part of the on-going program to provide for the proper defense for the United States. The Department of Defense has an established process for planning and conducting operational tests and for evaluating the data that result from those tests.

The role of modeling and simulation in this OT&E activity has grown in importance in recent years. Modeling and simulation (M&S) can be important supplements to the actual operational testing of new defense systems. In the operational suitability area, M&S can be even more important. Through M&S, the critical suitability aspects of a system and the compatibility of the weapon with its support system can be examined. This report was prepared to highlight the reasons why M&S is used in the operational suitability area of OT&E and to describe some of the key process steps that are needed for effective application of M&S.

It should be noted that the application of M&S also will vary with size, scope, and complexity of the system, and the acquisition phase of the system. Some tools and techniques are scalable from small systems to very large systems. For small systems, spreadsheets or small simulation models may suffice. In some cases, these same tools may be of great value for very large systems. There also are tools and techniques that are very useful from the early concept development phase well into production and fielding. While the focus of this document is on larger systems, the concepts, processes, and many of the models and techniques apply across all systems.

The report is organized in the following manner. Chapter 1 discusses the importance of operational suitability, and some of the reasons why M&S is needed for effective operational evaluation of most defense systems. Chapter 2 discusses the use of M&S in the operational suitability area. Chapter 3 describes the role of M&S and provides an outline for a generic approach to operational suitability M&S. Chapter 4 contains example applications of M&S to the OT&E of systems. Chapter 5 provides a summary of the information that is in the report. The Appendix comprises summary information on 12 models that have been used in the operational suitability area. Summary charts that provide a composite view of all the areas covered by the 12 models and that indicate the applicability of each model to the respective suitability areas also are included in the Appendix.

If questions or comments arise while reviewing or using this document, they should be forwarded to the primary author:

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Chapter 1
INTRODUCTION

The importance of Operational Suitability (OS) is no longer in question. Dozens of Department of Defense reports, contractor studies, case histories, and results from combat operations provide conclusive evidence that operational suitability factors are not only critical to the mission performance of weapons systems, but also easily account for more than half of total weapon system costs. Table 1-1 provides a list of some of the DoD efforts directed toward evaluating operational suitability, and the efforts undertaken to improve the suitability of new weapon systems.

Table 1-1.

OPERATIONAL SUITABILITY STUDIES AND IMPROVEMENT EFFORTS

EFFORT	IMPACT	DATE PUBLISHED
Navy "New Look" Reliability Program	Major Overhaul of Navy Approach to Reliability	1975
Carlucci Study on Improving The Acquisition Process	Actions in Incentives, Funding, and Acquisition Management for R&M and Support	1981
Report of The Defense Science Board 1981 Summer Panel on Operational Readiness with High Performance Systems	Recommendations for Improving Reliability Standards for Operational Availability, Spares Purchase and Distribution, Visibility of System-by-System Readiness, and for the Establishment of OSD-Level Readiness Advocate	1982
IDA/OSD R&M Study	An Analysis of New Technology and Potential Contributions to R&M Problems in Their Application, as well as Impact on Achievement of Desired R&M Goals	1983
U.S. Air Force R&M 2000 Initiative	The Establishment of Goals, Principles, and Building Blocks for Improving Combat Capability Through R&M	1985

Manpower, spare parts, support equipment, technical data, training, sustaining engineering, and software maintenance are major direct cost elements, both during the acquisition process and throughout the life cycle of the system. In addition, some cost effects of the operational suitability elements show up only when in the aggregate. An example is the need for more manpower, or other suitability elements, due to shortfalls in one or more of the suitability areas such as reliability, maintainability, or support equipment. Critical effects also can be felt in terms of system downtime, lost or ineffective missions, lost or destroyed equipment, or injury to personnel.

1.1 Operational Suitability Continues To Be a Problem

Despite the widespread appreciation of its critical role, incorporation of operational suitability factors continues to present significant problems in most weapon system development programs. Given the clear evidence that excellence in OS is a necessary attribute of successful systems, why is it still a problem on many systems? There are at least two categories of factors that contribute to this situation. The first relates to *the nature of suitability factors themselves* and the second concerns *the manner in which suitability is viewed* by the development managers.

1.1.1 Operational Suitability Factors

The nature of suitability factors themselves -- their essence makes it difficult to manage and control operational suitability during system development. For example, one of the key obstacles is the inability to directly and quantitatively assess reliability and maintainability (R&M), or supportability elements, early in the development process because data required to do this type of assessment come late in the development process. Yet, if managers wait until hard, tangible results are available before they assess an operational suitability product, such as technical data or support equipment, an opportunity will have been missed. They will be unable to identify and correct problems before the expenditure of significant amounts of program funding. Thus, program managers must include provisions for monitoring and controlling suitability progress within their program management tracking systems.

The second set of factors -- *the manner in which suitability is viewed* -- is distinctly different than the first, although its manifestation is rooted therein. Since suitability elements are among the final pieces of a system to be completed, funding for their development usually is still "on the table" when the system gets into trouble. Thus, the *funding* for the suitability elements is available and vulnerable for reallocation.

1.1.2 The Calculated Risk

To those who stand outside the system development process, the fact that systems are developed and delivered with serious suitability problems seems bizarre. Why would a company begin delivery of a newly designed television, automobile, software program, tank, ship, or aircraft when the support elements are missing, or incomplete? In fact, this calculated risk often is taken. Most people have experienced or have known someone who has experienced buying a new automobile, having a problem, and finding that the dealer does not yet have the equipment to test the system, or the mechanics trained to fix the problem. This is even more likely to happen with a new piece of software.

Why is the calculated risk taken? Why are products delivered with incomplete support or low quality suitability attributes? It is, in effect, because the customer needs or wants something badly enough that he/she will tolerate potential problems, and their effects.

There also are situations within the marketplace that stimulate the taking of calculated risks. For example, with a new, hot item that other competitors are close to delivering, managers can be lead into a decision to deliver without complete testing or without full support. The environment within which defense systems are developed also can make these calculated risks attractive; for example, when development money is depleted and further support from the Services or Congress, without deliveries, is not likely. Another possible stimulus is the situation where too many new or advanced systems are competing for development within total available funding. The assignment of unrealistically low funding to a program almost always has a negative impact on the quality of the suitability elements being developed for that program.

Accordingly, as long as the conventional wisdom says that this calculated risk is a good risk, i.e., experience supports the action, there will be examples of where the risk will be taken. It probably will be financially rewarding for the company, and the customer will receive a system that is not perfect, but is better than the one it replaces.

This type of dilemma is not unusual and provides one of the compelling reasons for strong analytical (including M&S) support for OS. The ability to provide timely quantitative INSIGHTS and IMPACT statements is absolutely essential.

1.2 The Operational Suitability Challenge Must Be Met

One of the greatest challenges in the operational suitability arena is to be able to assess the potential impact (or cost) of the risk from the customers' perspectives. The objective is to quantify the risk in a clear and concise way, and in terms that are understandable to the decisionmaker. Most importantly, this quantification and assessment must be completed within the timeframe of the decisionmaker's commitment to buy.

The most desirable approach is actual testing! -- testing of representative equipment, employed in its intended environment, operated and maintained by representative military personnel, and operated at a pace and scale that is representative of its intended use. In numerous cases, these conditions cannot be attained, yet the decisionmakers require quantitative inputs.

This challenge for quantification provides the motivation for using modeling and simulation (M&S) in the area of operational suitability. M&S can provide the structure and the process to

- identify and assemble the required, detailed information,
- store the data in a structured way,
- facilitate dialogue among contractors, program management personnel, users, and testers,
- provide a mechanism for exercising the assembled data structure in various scenarios,
- contribute to the database for trade studies, and
- provide an assessment of the impact of suitability shortfalls.

1.3 Special Problems Associated with Operational Suitability Testing

The test and evaluation (T&E) community has a specific requirement to assess the suitability of each system. Meeting this requirement presents some significant problems because there are many limitations to testing capability in the OS area including funding, the availability of tangible assets, the realism of the available test assets, the number of test assets available, the numbers and realism of the test events, and the incorporation of evolving technologies. The following sections discuss issues associated with these limitations.

1.3.1 Front-End Funding for Suitability Items

There is a tendency to delay or underfund suitability elements in the early phases of acquisition. The reason often given is that the suitability products are not required until later. The work breakdown structure (WBS) may even support this rationale because of its inherent weakness in stressing that the core material for input to the suitability products be developed early in the acquisition, and be captured and identified as such.

1.3.2 Availability of Tangible Assets

During the early phases of acquisition and prior to Initial Operational Test and Evaluation (IOT&E), typical test assets are conceptual models, early prototypes, brassboards, and hot mockups. These assets are developed for the purpose of proving design concepts and demonstrating feasibility, as well as other objectives that are specifically aimed at Operational Effectiveness (OE) issues. The situation is not significantly different at the point of IOT&E. Often, the logistics support infrastructure is not sufficiently developed prior to a Limited Rate or a Beyond Limited Rate production decision to completely evaluate all operational suitability areas. Table 1-2 summarizes, for a nominal system, an assessment of the availability of suitability test assets at the acquisition milestones.

Table 1-2.

AVAILABILITY OF OPERATIONAL SUITABILITY TEST ASSETS

OS TEST ASSETS	MS-0	MS-I	MS-II	MS-IIIA	MS-IIIB
Hardware	Nz	Nz	Nz	Min	Sat
Software	Nz	Nz	Nz	Nz	Min
Technical Data	Nz	Nz	Nz	Nz	Min
Diagnostic Systems	Nz	Nz	Nz	Nz	Min
Support Equipment	Nz	Nz	Nz	Nz	Min
Training Material	Nz	Nz	Nz	Nz	Min
Spare Parts	Nz	Nz	Nz	Nz	Nz
Service Personnel	Nz	Nz	Nz	Min	Sat

LEGEND: Nz = Near zero
Min = Minimum
Sat = Satisfactory

1.3.3 Test Asset Fidelity

Table 1-2 above attempts only to show "availability" of the OS assets that would be required to run an operational test of sufficient scope to produce credible results. A further problem is that, even on full-scale development models, many of the assets that are available are not "production or production equivalent." Thus, suitability testing or assessment data must be carefully examined and analyzed before presenting any results.

1.3.4 Sample Size

The sample size issue goes further than the number and fidelity of test assets discussed above. Most development and operational test designs are structured to provide sufficient replications to measure Operational Effectiveness (OE) objectives. Even with this focus, the OE replications are not always achieved because of the limits on the cost of testing. In nearly every case, the limited number of test hours provides a less than ideal confidence level in most of the operational suitability results.

1.3.5 Test Scenarios

Test scenarios are nearly always driven by OE requirements and objectives. Again, this is not to imply that achievable levels of testing always are sufficient for OE objectives and that merely the testing for operational suitability is limited. In fact, it is seldom cost effective to approach the projected combat pace during OT&E, yet many of the logistics measures of interest are best measured at or near the expected pace of combat. How do we replicate the surge of a combat unit with only a few test articles?

There are other scenario issues as well. Should both peacetime and wartime operating scenarios be examined during the testing? How realistic should the test environment be in comparison with the intended operational environment? Is it possible to evaluate the suitability characteristics in an intended, realistic operational environment (including weather, shock, vibration, dust, water, battle damage, etc.)? In nearly all cases, there is an inability to use or test the total interface to the planned support system.

1.3.6 New Technology

Another significant challenge is the incorporation of constantly evolving new technology into military systems. Driven by the need to stay ahead of the evolving threat, there is a constant search for advantage through the application of the latest technology to defense systems. The impacts on OS and OE testing are similar. Advanced technology systems result in an on-going need to examine test methods, and to develop and refine them accordingly.

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Chapter 2
THE ROLE OF OPERATIONAL SUITABILITY M&S

Modeling and simulation can play a significant role during test and evaluation for operational suitability. As discussed in section 1.2, M&S can provide the structure and the process to (a) identify and assemble the required, detailed information, (b) store the data in a structured way, (c) facilitate dialogue between contractors, program management personnel, users, and testers, (d) provide a mechanism for exercising the assembled data structure in various scenarios, (e) contribute to the database for trade studies, and (f) provide an assessment of the impact of suitability shortfalls.

The essential utility of the model is its value in dialogue and communications. As can be seen above, there is no case where M&S for suitability is not required. Even in the best case -- full recognition of the criticality of suitability and support for suitability funding -- there are shortfalls. The operational suitability asset availability still has voids, and issues such as asset fidelity, test scenarios (e.g., pace of combat), and interface to the support system can be reasonably easy to handle in a model.

2.1 Definitions of Modeling and Simulation

A model is defined in DoD 5000.3-M-1 as "... a representation of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations that can be used to predict how the system might perform or survive under various conditions or in a range of hostile environments."

Simulation is defined in DoD 5000.3-M-1 as "... a method for implementing a model. It is the process of conducting experiments with a model for the purpose of understanding the behavior of the system modeled under selected conditions or of evaluating various strategies for the operation of the system within the limits imposed by developmental or operational criteria." There are different types of simulations, including those that use analog or digital devices, laboratory models, or "testbed" sites. Simulations, in the broadest sense, also can include military exercises and wargames.

2.2 Use of Suitability M&S

The use of properly validated M&S is strongly encouraged during the early phases of a program to assess those areas that cannot be directly observed through testing. The use of M&S is not a substitute for actual testing; however, it can provide early projections and reduce test costs by supplementing actual test data. The DoD is in the process of issuing expanded guidance on the development, validation, and use of M&S in the acquisition process. In January 1989, the Director of Operational Test and Evaluation (DOT&E) issued "DOT&E Policy for the Application of Modeling and Simulation in Support of Operational Test and Evaluation."

The use of modeling and simulation in the operational suitability area can provide a significant number of benefits. For example, M&S can be used to focus limited test resources by identifying critical elements in a logistics support system, e.g., the choke points for the flow of the support resources. M&S can be used to translate the rate of use in the test scenario to the wartime usage rate. If test aircraft are flying only one or two sorties per day, the "load" on the support resources is significantly different than if a higher, wartime sortie rate were being flown. M&S can aid in assessing the impact of these differences. M&S also can be used to evaluate elements of the support system that are not present at the test site. If the second-level maintenance capability, e.g., test equipment, facilities, etc., is not available, then a properly constructed and validated model can be used to provide insight into the ability of the planned second-level maintenance facility to support the system.

The Appendix to this report contains summary descriptions of 12 M&S approaches that are being used or developed for application to operational suitability. These summaries indicate the application area of each item, and provide a short description of the capabilities provided.

2.3 Considerations in Suitability M&S

M&S plans should be evaluated to ensure credibility of the results. Such creditability derives from a composite impression of the assumptions, inputs, processes, outputs, conclusions, persons or agencies involved, and the strength of the evidence presented. Appendix B of the "DOT&E Policy for the Application of Modeling and Simulation in Support of Operational Test and Evaluation" provides a series of questions to assist in addressing the credibility of M&S results. These questions provide a good outline for examining M&S activities.

Detailed definitions of planned operating and support scenarios are essential for a valid M&S effort. In many cases, a detailed definition beyond that in program documentation is needed for M&S. This is particularly true for the concepts that pertain to the maintenance and supply activities supporting the system. This requirement for expanded detail can have disadvantages as well as advantages. For example, it is difficult to apply M&S to a situation that is not defined in adequate detail; there is potential for the results to be driven by some of the necessary assumptions rather than by the system characteristics; and the persons conducting the modeling may end up being a greater part of the solution than desired, and the model results subsequently may be challenged. On the other hand, if the responsible personnel and organizations provide the required definition and detail, then a portion of the detailed support planning will be completed and will have a benefit to others within the acquisition program. The key point is -- what assumptions were made in structuring the model and were those assumptions realistic in everyone's mind.

Furthermore, the latest program information must be incorporated into an M&S activity. A common fault of many modeling efforts is this lack of most recent information. Program conditions may change. The system design may be revised, or new threat information received. In each case, the earlier model may be invalidated. Assuring that the modeling results reflect the best information available is an important consideration. Procedures need to be established to assure that current information is provided to those performing the modeling and evaluating the results.

2.4 Where M&S Fits

In many situations, there is no substitute for the real thing. In the test and evaluation arena, this means "hands-on" testing by appropriate Service personnel, using the real product, in the intended operational environment, at the pace of battle, and with the intended support structure. Reality has it differently, however. Cost, time, political considerations, and other factors must be constantly reviewed and balanced. Any move away from the ideal will entail risk. The science and art of both developmental and operational testing is to design and maintain a balance where the risks are acceptable.

T&E management in the intricate world of military acquisition is one of the most complex and politically charged jobs one can imagine. It follows that the range and depth of the tool kit required by the test community to accomplish their job is likewise complex. M&S is one of those tools. Proper application of M&S is, among other things, an integration issue. Whether the top level T&E plan for a system is a Test and Evaluation Master Plan (TEMP) or a Service T&E plan, it must reflect the balance.

Chapter 3
STRUCTURED APPROACH FOR THE USE OF M&S

The structured process for the use of M&S to fill gaps, integrate disparate information, cross check test results, and provide balance is outlined in Table 3-1. Specific areas where shortfalls likely will occur are discussed in this chapter. The selection and application of models and simulations must be in concert with an overall test and evaluation plan, or approach. Sections 3.1 through 3.9 provide detailed discussions of each of the items outlined in the the table.

Table 3-1.

OPERATIONAL SUITABILITY MODELING AND SIMULATION APPROACH

- Operational Suitability T&E Planning
    1. TEMP Coverage
    2. T&E Planning
    3. Model Requirements Analysis
    4. Model Selection or Development
    5. Model Verification and Validation (V&V)
    6. Model Accreditation
- Phasing the M&S Activity With the Test Activity
- Using Comparability Analysis and Other Tools
- Using T&E Data (DT&E, as well as OT&E)
- Crosschecking and Revalidation of Assumptions
- M&S Results as an Input to Focus the Testing
- Model and Data Management
- Presentation of Data to Decisionmakers
- Understanding and Avoiding M&S Hazards

3.1 Operational Suitability T&E Planning

M&S requires planning and integration with other T&E activities. The selection of the appropriate model or modeling environment, and the verification and validation (V&V) of the models, are critical elements of this plan. Sections 3.1.1 through 3.1.5 detail each of the planning steps that are shown under OS T&E planning in Table 3-1.

3.1.1 Test and Evaluation Master Plan (TEMP) Coverage

The development of a TEMP is part of the top-level process for designing a T&E program for major systems. Information required to resolve critical issues and questions should be identified. If data from DT&E and/or OT&E will not be available or will not be of sufficient detail to resolve those issues and questions, then the use of M&S becomes a strong candidate for supplementing the actual test data.

If the use of M&S is anticipated for early assessments in a weapon system test program, then it should be indicated in an early TEMP. Defined plans for the use of M&S should be presented in later TEMPs. The definition of M&S activities should include M&S objectives, Measures of Effectiveness (MOEs) to be studied or modeled, a list of the assumptions inherent in the effort, expected inputs to the M&S effort, expected outputs, a phasing plan for times and places for data availability, the amount and kinds of resources allocated to the M&S effort, and a list of models and simulations that might fit the requirement. As more definition is developed, the models to be used should be identified and plans for their validation described.

3.1.2 Test and Evaluation Planning

Once the determination to use M&S has been made and the information detailed in section 3.1.1 is made available, an M&S plan should be developed. This will contain an expansion of the above information, as well as a more detailed plan for model application. Additional details should include a model selection plan, a model verification and validation (V&V) plan, a detailed resource requirements analysis, and a plan for integration with all other components of the top-level T&E plan.

3.1.3 Model Requirements Analysis

The analysis of model requirements is based on the needs identified in the top-level plan. The requirements are further refined during the T&E planning phase, and documented in the model selection plan. Some of the key factors are the availability and stability of input data, the measures of effectiveness of interest, the granularity (precision) of the model, special hardware or software requirements, cost of operation, and other factors, such as the level of V&V needed.

3.1.4 Model Selection or Development

With the requirements established and the model selection plan completed, the process of reviewing existing models and assessing the time and level of effort needed to develop new models is an accomplished fact. Use of a structured requirements approach facilitates efforts to maintain a balance in this area.

3.1.5 Model Verification and Validation (V&V)

T&E results are being increasingly scrutinized at all levels within and outside the government. Credibility of M&S evaluations is constantly questioned and, as a result, verification and validation of the respective models must be given special consideration and attention. V&V results must pass the scrutiny of knowledgeable and informed decisionmakers. The "DOT&E Policy for the Application of Modeling/Simulation in Support of OT&E" contains the following:

> Verification is the process of determining whether a computer program or a simulation model performs as intended. A verification plan must be prepared for M/S planned for use in operational test and evaluation. This plan must be referenced in the weapon system Test and Evaluation Master Plan (TEMP). For new and modified simulation models, the verification plan must describe the verification process(es) and the documentation for reporting verification results. For existing simulation models, previous verification efforts which led to accreditation, if any, must be referenced.

Validation is the process which, as a minimum, addresses the following primary concerns: (1) the appropriateness of the model to adequately answer the questions or issues under study; (2) the degree of confidence in the conclusions that can be drawn from the M/S results; (3) the appropriateness of the threat data and threat tactics used in the model; and (4) model consistency. A M/S is appropriate if it addresses the critical issues and the supporting Measures Of Effectiveness (MOEs), and if the M/S is a realistic representation of the weapon system and its operational environment. M/S appropriateness depends on the modeling techniques, assumptions and limitations, the input sources and quality, the ability to measure performance, and the design of the experiment. Confidence in M/S results can be enhanced by comparison to other data, e.g., actual test results, other models, or historical data. The sensitivity (driving and limiting factors) should be well understood and documented. Plans to recalibrate, reverify, and/or revalidate models and simulations based on actual test results also should be documented and implemented.

3.1.6 Model Accreditation

The "DOT&E Policy for the Application of Modeling/Simulation in Support of OT&E" defines accreditation as:

> "the process of certifying that a computer model has achieved an established standard such that it can be applied for a specific purpose."

Accreditation is approval by management -- based on experience and expert judgment -- that a model is adequate for its intended use. The accreditation mechanism recognizes that V&V of a model are continual processes and that full validation of the model may not be technically or economically feasible. Accreditation is possible even if the model is not fully validated, but it does not lessen the need for continuing to work toward full V&V.

3.2 Phasing the M&S Activity with the Test Activity

The M&S plan must be coordinated with other test activities. This will ensure that data availability and quality issues are considered. Other phasing issues include due dates for reports, availability of test assets, test schedules, and test coverage.

3.3 Using Comparability Analysis and Other Tools

At times, the fidelity of test assets may be adequate for meeting most operational effectiveness objectives (i.e., brassboard, breadboard, prototype being tested for proof of concept), but inadequate for testing suitability objectives. In many cases, specific components of the support structure (e.g., support equipment, technical data, diagnostic software, etc.) are not available in a timely manner. As will be discussed in the examples in Chapter 4, there are tools and techniques, such as comparability analysis, that have been applied very successfully to supplement actual test data. These techniques permit an earlier assessment of suitability issues and a more timely identification of critical design features.

3.4 Using T&E Data (DT&E, as well as OT&E)

The utility and sensitivity of DT&E data should be assessed. In many cases, the increased dialogue and the better understanding of data needs by the two communities are of great value not only for M&S use, but also for providing additional test data for the OT&E evaluation process.

3.5 Crosschecking and Revalidation of Assumptions

In any analysis, there are crosschecks that must be accomplished to ensure consistency and quality results. The revalidation of the assumptions inherent in the results is critical, and is often overlooked in M&S. It is good practice to develop an illustration for use in reports or briefings that clearly documents the assumptions. One format that has been used is a "balance chart" that lists "Factors and Assumptions That Lead to Optimistic Results" on the left and "Factors and Assumptions That Lead to Pessimistic Results" on the right. This type of illustration provides a beneficial tool to the user of the M&S results.

3.6 M&S Results as an Input to Focus the Testing

As is reported in the examples in Chapter 4, a powerful result of M&S is providing information that can significantly improve the focus, cost effectiveness, and ultimate value of traditional testing. For example, early assessment of the operational suitability of the E-3A identified and helped to quantify the criticality of the diagnostics system. This assessment assisted in the definition of diagnostics MOEs and the design of the actual testing.

3.7 Model and Data Management

The importance of this area cannot be overemphasized. If model configuration is not controlled and V&V is lacking, the results are, at best, suspect and, at worst, disastrous. Likewise, the input data must be managed, controlled, and verified. Model and data management must be a part of the M&S plan, with proper resources identified and obtained.

3.8 Presentation of Data to Decisionmakers

The best of models and simulations and their results are of little value if the presentation of those results is poorly done. It is not as important that a specific presentation format be used as it is that the presentation be designed to meet specific objectives. There first must be agreement on the objectives. If possible, they should be in writing. The key is to present the data and the information in a form and in parameters that the intended audience can relate to. In defense systems, examples of parameters that are important to operational commanders are effective combat sorties, miles steamed, targets destroyed, probability of mission success, numbers of systems lost, and time to restore to mission-capable status.

3.9 Understanding and Avoiding M&S Hazards

The hazards in the application of M&S are not unlike those in any endeavor -- rushing results, no time for V&V, poor or incomplete planning, inadequate funding, untrained or inexperienced M&S personnel, results that very few may want to hear, "my model versus your model," junk data, undocumented assumptions, lack of model controls, lack of data controls, "tinkering" with model results, etc. Most of these are common problems. The best defense is, again, a good offense. Do not skimp on the planning. The well structured M&S plan should address each of these potential problem areas.

Chapter 4
EXAMPLES OF SUITABILITY M&S

This chapter presents three examples of the application of M&S to operational suitability topics within an operational test and evaluation environment. These examples, all drawn from OT&E, are included to show the breadth of M&S applications and to demonstrate the effectiveness of some of the methods employed in providing information to decisionmakers.

4.1 The F-16 Aircraft

The example of the F-16 fighter is one of the best representations of a continuous suitability modeling and simulation effort throughout the acquisition phases of a system. This M&S effort began during the competition between the F-16 and the F-17 in the early 1970's and continued through the end of the FOT&E in the early 1980's. The simulation model continued to be updated and used for maintenance manpower analysis even after the test program was completed. The primary model used was LCOM (Logistics Composite Model), although other models, using QGERT and its successors, SLAM I and II, also were developed and applied. This coordinated M&S effort addressed a wide spectrum of application areas, as is reflected in the following:

- In order to develop models of the two competing designs during the flyoff, comparability analysis was used to both develop representations of each aircraft design and to compare the two designs. Two segregated teams developed the models of each aircraft. The teams worked with the respective contractors and program office personnel, as well as using command personnel in developing the models.

- Sortie generation, availability, maintainability, manpower, configuration baseline, and other decision criteria were analyzed. One key area of the analysis was the comparison of the one-engine design of the F-16 with the two-engine design of the F-17.

- During both IOT&E and FOT&E, an LCOM-developed model was applied to the analysis of specific deficiencies identified during operational testing. Well over 200 deficiencies were analyzed. The primary question for each deficiency was "what is the real impact?" This M&S activity assisted in answering the impact question for those deficiencies that existed in the operational suitability arena. The results were very effective and were used by the decisionmakers. This process was named QED (Quantitative Evaluation of Deficiencies). It was lauded by the Commander of the using command, the OT&E agency, the government program manager, and the developing contractors.

- The models also were used during the entire acquisition period to develop manpower projections and to determine the manpower standard.

- A companion model to LCOM, TAC FLIER, was used to analyze and estimate the aircrew ratio as part of the process to determine the required aircrew manpower.

This broad-based M&S effort spanned nearly ten years. Even today, it can be considered as a standard for effective application of M&S. The models were always considered "tools" for decisionmakers and served as "communications baselines" among users, the program office, the contractor, and developmental test and operational test personnel. The models were useful in refining requirements and promoting a better understanding of the operational scenario and its impact.

4.2 The E-3A AWACS

The application of operational suitability M&S to the E-3A AWACS is another example of an early application of M&S that continued throughout the acquisition phases. M&S was used from the "brassboard" prototype of the E-3A in the mid-1970's to well after the FOT&E in the early 1980's. As with the F-16 example, M&S was applied in a variety of areas. Analysis of processes such as maintenance, integrated logistics support issues, operational scenario impacts, requirements analysis, and training were accomplished. Some specific M&S activities included the following:

- Early requirements and requests for decision information led to some spreadsheet-type analysis using the scenario information and the data that were being assembled for building the more detailed modeling tools. Due to the overriding impact (open-the-door costs) of dispersion of the aircraft to geographically separated operating locations, results from very high level (macro) models were especially accurate and useful very early in the program.

- The flow of maintenance for the mission avionics was especially critical, due to the heavy reliance on the diagnostics system. Models were used to evaluate alternative plans for maintenance "work arounds" for subsystems where the diagnostics fell short. That work led to further analysis and identification of additional training requirements and the need for "beyond BIT" (built-in test) technical data; that is, when the BIT no longer can aid in troubleshooting, what procedures should be followed?

- One special aspect of the M&S effort was the heavy involvement of the Air Force system support manager from Oklahoma City Air Logistics Center. Many special investigations of the spare parts requirements and depot activities were carried out because of this involvement.

- Later in the program, fully developed models, using LCOM, were used (as in the F-16 example) to analyze the impact of deficiencies and to design unique support techniques to achieve maximum results with limited resources.

4.3 Intermediate Level Test Stations

In this example, an early analysis determined the quantity of maintenance test stations that were needed for each operational unit. This analysis was flawed. The use of a steady state analysis resulted in an estimate of a test station quantity that could not support the wartime sortie rate planned for the aircraft.

- The use of a squadron-level simulation model using the LCOM included modeling the intermediate-level, automatic-test-station environment. The model used realistic reliability and maintainability values for the system components and the planned system utilization to ascertain if the test station complement could satisfy the wartime sortie requirement. The simulation indicated that additional stations were required.

- The earlier assessment of the true situation permitted the program manager to obtain additional funding and to increase the number of test stations provided to the operational units.

Chapter 5

SUMMARY

The importance of Operational Suitability is not in question! Suitability related elements of defense systems are critical to mission performance and easily account for more than half of weapon system costs.

There are both direct and indirect areas of suitability cost. The direct areas include such suitability elements as manpower, spare parts, support equipment, technical data, training, sustaining engineering, and software maintenance. The indirect areas are those in which some effects of operational suitability elements show up in the aggregate. These indirect areas are especially well suited to M&S because even with "full-up," "hands-on" testing, the aggregate effects of small problems are virtually impossible to see, and the need for additional manpower or other support, due to shortfalls in suitability areas such as reliability, maintainability, or support equipment, can be quite dramatic. Other indirect effects such as downtime, lost missions, ineffective missions, and lost or destroyed equipment or personnel also can be effectively addressed through M&S.

The payoffs from M&S activity are high leverage, and offer very high benefit-to-cost ratios. Some of these payoffs include:

- Early identification of issues and critical areas.
- Identification of key objectives to better focus other phases of test and evaluation.
- Assessment of the sensitivity and impact of key design areas, such as diagnostics.
- Improved communications on important factors, such as the planned operational and support scenarios.
- The ability to provide impact assessments that are critical to the effectiveness and ultimate utility of T&E to the decisionmaker.

The T&E community faces some exceptional challenges in the future. To meet these challenges, operational suitability M&S is a powerful tool to add to the T&E tool kit. It has been applied very successfully in the past and can be applied even more effectively in the future. It also can be misused and abused. The better it is understood and the more that is learned from experience, the better prepared we will be to profit from the application of operational suitability modeling and simulation.

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Appendix A

MODELING AND SIMULATION SYSTEMS, ENVIRONMENTS, AND MODELS

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Appendix A

M&S SYSTEMS, ENVIRONMENTS, AND MODELS

Introduction

This Appendix presents some examples of simulation and modeling tools that may be considered for use in the performance of Operational Suitability (OS) analysis. The examples presented consist of tools currently in use or in the final stages of development or testing. Each is described using a standard format, including basic model data, point of contact, and system requirements (hardware/software). The models and systems described are classified into one of the following three categories:

Automated Systems: An automated system is a deterministic model that lacks random events. It may be a manual process that has been automated to save time. This category also includes spreadsheet applications.

Simulation Environment: A simulation environment provides the analyst with a system to create models when the need for a specific application exists and a model has not been developed. The analyst is provided only the necessary tools to develop the model. The environment has a language (i.e., SLAM II or SIMPLE_1) that may be used to construct a simulation model. It also incorporates the functions necessary to simulate the passage of time (timing routine), to track events, and to gather statistics on entities, events, and queues during the simulation.

Simulation Model: A simulation model comprises an application that models random events, simulates the passage of time, and performs data collection. The model is designed to perform in a standard way, providing consistent (although not necessarily the same) data from one run to the next.

Examples of the defense systems for which each model was applied are provided. The following categorization of systems is used:

Ships: Any surface or submarine vessel.

Land Vehicles: Any system designed to operate on land, including tanks, trucks, etc.

Air Vehicles: Any vehicle designed to operate above the earth's surface, but remain within the earth's atmosphere. This includes all conventional aircraft (fixed-wing and rotary wing).

Space: Any system, vehicle, or platform designed for and used in space, including low-earth-orbit vehicles.

Field Equipment: Any piece of powered or non-powered equipment needed to support a weapon system or operational system. Field equipment includes ground power units, air conditioners, and field test sets.

Command and Control (C&C): Any system or platform used to perform command and control functions, including airborne radar platforms, ground radars, and the communications facilities required to operate the command and control systems.

Missiles: Any air-to-air or air-to-ground weapon, including defensive and offensive weapons, excluding ground-to-air defensive weaponry.

Air Defense: All weapons designed to destroy or counter airborne threats, including rapid fire cannons (i.e., Phalanx CIWS) and surface-to-air missiles (i.e., PATRIOT). This category does not include the command and control function.

The efforts used to verify and validate the example systems also are described. In addition, a brief overview is presented, followed by an illustration that depicts the utility of the model to address the operational suitability areas of availability, sustainability, reliability, maintainability, provisioning, and manpower.

The dark shading on the illustration represents the area(s) of primary application of the model; light shading is used to reflect secondary areas that offer the greatest potential for additional application of the model's capability. The numbers in the squares refer the reader to the notes below the chart which provide further discussion.

In the case of the summary charts (page A-37), the numbers in the squares show which models are applicable for each of the respective areas. The survey summary is provided (pages A-36, A-37) to illustrate the total coverage for the various models. Shading is used to depict the applicable areas of coverage, presenting the reader with a broad picture of the capabilities offered by surveyed systems and models.

This Appendix consists of the following examples:

Automated Systems:

1. Aviation Readiness Requirements Oriented to WRAs (ARROWS)
2. Weapon System Reliability Model (WSRM)
3. Spreadsheet Models

Simulation Environments:

4. Modeler's Workbench
5. Simulation Language for Alternative Modeling (SLAM II)
6. SIMPLE_1

Simulation Models:

7. TRASANA Aircraft Reliability and Maintainability Simulation (TARMS II)
8. Combat Analysis Sustainability Model (CASMO)
9. Logistics Composite Model (LCOM)
10. TIGER
11. Comprehensive Aircraft Support Effectiveness Evaluation (CASEE)
12. Comprehensive Operational Support Evaluation Model for Space (COSEMS)

Simulation Survey Summary

AUTOMATED SYSTEMS

Aviation Readiness Requirements Oriented to WRAs (Weapon Replaceable Assemblies) (ARROWS)

Model Category:	Automated System

Point Of Contact:	Mr. Frank Struch, Fleet Material Support

Telephone:	Commercial	(717) 790-5205	Autovon	430-5205

Hosted On:	Various Navy Computers

Coded In:	Focus, COBOL, and FORTRAN

<u>Model Applications:</u> This model has been applied to a wide variety of Naval aircraft and support equipment for the purpose of defining budget requirements. It presently is being applied to the V-22 program.

<u>Verification:</u> The verification process must include a thorough review to ensure the ARROWS Model will perform as designed. When the ARROWS Model is used as part of OT&E, results of this verification effort must be documented and included in the Test and Evaluation Master Plan (TEMP).

<u>Validation:</u> Model validation was accomplished by the Fleet Material Support facility in 1986. The test consisted of data obtained from the 1986 deployment of the USS Enterprise and its contingent of F-14 aircraft. Data on 701 organizational maintenance items were collected and entered into the 3M standard Navy data system. These data were used with the ARROWS Model to make predictions of parts failures, parts availability, repair times, and spare-based requirements. The ARROWS Model output was compared to actual operational data, with results being very close.

<u>Purpose:</u> ARROW is a stochastic, analytical model used to determine aviation spares requirements to support the Navy consumer-level spares program. It may use the Navy standard database for input data, or data provided by the user. The primary inputs are reliability and maintainability data for each part under consideration.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY								
SUSTAINABILITY								
RELIABILITY								
MAINTAINABILITY								
PROVISIONING			1		1			
MANPOWER								

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Provisioning: The user inputs R&M data for each part, and the model predicts the spares required. It also can be used to determine spares requirements for shore-based aircraft or shipboard aircraft maintenance.

Weapon System Reliability Model (WSRM) [Formerly named - Mission Critical Success Probability (MCSP)]

Model Category:	Automated System		
Point Of Contact:	Mr. Neal Chamblee, USAF, AFOTEC		
Telephone:	Commercial (505) 846-1264	Autovon	246-1264
Hosted On:	VAX 11/780		
Coded In:	FORTRAN		

Model Applications: This model has been used successfully for the B-1B, F-15E, and F-16 programs.

Verification: The model has been tested to ensure that the code is error free, and that it performs as designed. Output results were compared with previous manual calculations to complete the verification effort.

Validation: WSRM undergoes a validation process with each application. The AFOTEC simulation committee monitors the application of each model, including WSRM. Once the model is configured for a particular system, it is run using field data from a similar system. The results of the trial runs are compared to actual field data for the similar system to ensure the model is producing accurate results.

Purpose: The Mission Critical Success Probability (MCSP) Model has been renamed the Weapon System Reliability Model (WSRM). It is a deterministic model residing on the AFOTEC VAX computer system. A microcomputer version of the model is under development. The user inputs factors such as mission length, minimum essential equipment list, and hardware failure rates. The model then generates the expected reliability data that subsequently will be used in one of the simulation models used by AFOTEC (LCOM or a specific model developed in SLAM II). This model is best described as a preprocessor for simulation models.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY								
SUSTAINABILITY								
RELIABILITY			1					
MAINTAINABILITY								
PROVISIONING								
MANPOWER								

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Reliability: The model is used to determine expected system reliability given specific hardware failure rates and mission characteristics. Data from the model are used as inputs to simulation models. All events are deterministic. Randomness is not a model feature.

Spreadsheet Models

Model Category:	Automated System
Point Of Contact:	Not Applicable
Telephone:	Commercial: N/A; Autovon: N/A
Hosted On:	Various Computer Systems
Coded In:	Lotus 1-2-3, Multiplan, Supercalc, etc.

Model Applications: Spreadsheet models have been used extensively in OT&E of numerous weapon systems, including the U.S. Army DIVAD (Sergeant York) and the U.S. Air Force F-16.

Verification: The user must verify that the spreadsheet model performs as expected. If it is intended to use the model as part of the OT&E process, a verification plan must be included in the Test and Evaluation Master Plan (TEMP).

Validation: The user must ensure that the spreadsheet model is appropriate for the intended task. The results of the model must be consistent and defendable. Quality input data and careful experiment design will improve confidence in the model. Results should be compared with test data or actual historical data as an additional validity check.

Purpose: Spreadsheet models are constructed using various software packages, including Lotus 1-2-3, Multiplan, and Supercalc. These models normally are created and used on microcomputers. The main objective of spreadsheet analysis is to eliminate the need for manual calculations. The benefit derived from this application is the ability to conduct "what-if" analysis involving complex calculations and formulas. As the user inputs changes to the spreadsheet cell calculations, the entire spreadsheet reflects the latest changes. Once formulas are entered into the appropriate cells, the analyst is free to enter revised data for analysis. Many commercial spreadsheet software packages have built-in graphics functions to depict the data on X and Y, Bar, or Pie charts.

Using spreadsheet models, the user can specify cell location and data for a formula. This capability is extended in some available software to allow the user to specify external spreadsheets. Most spreadsheet packages permit the user to specify data inputs from other computer files and to direct output to a number of locations including a spreadsheet file, printer, computer screen, or a data file.

Spreadsheets provide user control and are very flexible and useful for early analysis where data are limited. Once the spreadsheet model is created, the user can input data as they become available, using estimates for unknowns until the actual data are collected.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY								
SUSTAINABILITY								
RELIABILITY								
MAINTAINABILITY								
PROVISIONING								
MANPOWER								

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

Spreadsheets have the flexibility to be useful in virtually all areas reflected on this chart. They lack a primary area of application, and therefore are shown as having secondary applicability in all areas.

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SIMULATION ENVIRONMENTS

Modeler's Workbench

Model Category:	Simulation Environment
Point Of Contact:	Mr. Doug Williams, Advanced Technology, Inc.

Telephone:	Commercial	(205) 895-0396	Autovon	N/A

Hosted On:	Symbolics
Coded In:	Common LISP

Model Applications: The model's initial application was on studies of the Advanced Launch System (ALSYM), a joint NASA/USAF program.

Verification: The Modeler's Workbench has undergone extensive reviews including peer code reviews, as well as unit, integration and production level testing to ensure the model performs as intended. When used in OT&E, the verification efforts must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: The Modeler's Workbench has not undergone validation as defined in 3.1.5 (see page 3-2). This simulation environment is designed to model space systems that are presently in the concept definition phase; therefore, comparison of predictions to actual system performance has not been possible. When these systems become functional, the model will undergo formal validation.

Purpose: The Modeler's Workbench is a set of programming tools for the development of knowledge-based models and simulations. It was developed on a Symbolics computer using Common LISP and the Flavors package as part of a comprehensive analysis capability.

The Modeler's Workbench comprises three major components: an object-oriented modeling environment, a rule-based inference package, and a discrete event simulation package. The modeling environment and simulation packages are designed to provide the user with an environment customized for the rapid prototyping of models and the simulations defined on those models. Once an approach has been selected, it has the flexibility to enable the prototype to evolve into a working simulation. In addition, a rule-based inference facility is incorporated to provide flexibility in developing a knowledge-based approach, as well as a procedural approach, to decisionmaking. Together, these features encourage and enhance an incremental development methodology to problem solving.

The initial application of the Workbench was to simulate operations of the Advanced Launch System (ALSYM). The ALSYM is a joint NASA/USAF program to develop an alternate launch vehicle for lifting heavy payloads into space. The primary area of interest to the modeler is the ALSYM logistics support infrastructure with emphasis on vehicle assembly, payload integration, and the refurbishment of reusable components. The infrastructure simulation is integrated with a reliability prediction model, a cost model, and a global evaluation model to provide a comprehensive assessment of resources needed to support the Advanced Launch System.

The Modeler's Workbench currently is being used to develop a simulation of the operation of the space station "Freedom." The primary area of investigation is the space station operational availability. The Modeler's Workbench permits analysis of tradeoffs among various design factors such as reliability and maintainability, and management factors such as the space station logistics support structure. Results of these analyses will reveal the impact of alternative combinations of these factors for decisionmakers to use in program management.

The Modeler's Workbench is used primarily for assessing reliability, maintainability, and availability characteristics of a system. In addition, a cost module provides costing per pound to orbit, as well as total life cycle costing information.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY				1				
SUSTAINABILITY								
RELIABILITY				2				
MAINTAINABILITY				3				
PROVISIONING								
MANPOWER								

LEGEND: = PRIMARY APPLICATION = SECONDARY APPLICATION

1. Availability: Applications developed with the Modeler's Workbench may be used to determine the operational availability of a space-based system (space station) or a launch vehicle.

2. Reliability: The Modeler's Workbench permits tradeoff studies to determine the reliability of the system to perform, given the available logistics support infrastructure.

3. Maintainability: Tradeoff studies may be used to optimize maintenance and logistic support structures, thus maximizing the systems operational availability.

Simulation Language for Alternative Modeling (SLAM II)

Model Category:	Simulation Environment
Point Of Contact:	Lt. Col. Kunkle, USAF, AFOTEC/LG4 *
Telephone:	Commercial (505) 844-0348 Autovon 244-0348
Hosted On:	VAX
Coded In:	SLAM II

Model Applications: SLAM has been used by AFOTEC to develop models for a variety of weapon systems, including the F-15E and F-16 aircraft and the SRAM missile.

Verification: The user must assure that the model developed using SLAM II performs as intended. This may consist of peer code review and examination of the network logic. AFOTEC instituted an internal model review committee to accomplish these verification tasks. The verification plan must be included in the Test and Evaluation Master Plan (TEMP) for all models intended for use in OT&E.

Validation: SLAM II is a simulation environment; therefore, validation must be an integral part of the process for building each model. The intended use of the SLAM II Model must be examined to ensure that it is suitable for the application. The model is considered appropriate if it addresses the critical issues and the supporting Measures Of Effectiveness (MOEs), and if it is a realistic representation of the weapon system and its operational environment. Validation plans and previous validation efforts must be documented and referenced in the TEMP. The degree of confidence in the model varies with the quality of input data, modeling techniques, and the experiment design. Confidence in the SLAM II Model may be enhanced by comparison of the output results to test data, other models, or historical data.

Purpose: SLAM II is a simulation environment. AFOTEC uses this model development environment to develop weapon-system-specific models. SLAM II uses FORTRAN for the development of special function subroutines and each model developed by AFOTEC makes extensive use of FORTRAN. These models are designed specifically to answer the questions encountered during operational test; they are unique to the weapon system for which they are developed. The user inputs standard scenario data, maintenance process flows, and maintenance resource availability. SLAM II models are useful during operational suitability assessments since each model can be specifically tailored to address the issues determined to be critical for the specific weapon system.

The use of SLAM II modeling techniques permits flexibility not available in traditional models. Careful consideration must be given to model accuracy with a clear and traceable audit trail for all model development decisions.

*NOTE: Questions on uses of SLAM II, beyond those at AFOTEC, should be directed to Ms. Sue Knoop, (317) 879-1011.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY			1	1			1	
SUSTAINABILITY			2	2			2	
RELIABILITY								
MAINTAINABILITY			3	3			3	
PROVISIONING								
MANPOWER			4	4			4	

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Availability: The analyst may constrain resources and determine the impact on a weapon system's sortie rate.

2. Sustainability: The simulation can be used to assess the ability of a unit to sustain operations, given constrained resources. One example of a possible application of a model written in SLAM II is "How long can the unit sustain combat operations with a limited set of spare parts, as in the War Reserve Spares Kit (WRSK)?" The level of resolution could be downsized to component level rather than unit level (i.e., the ability to keep the radar functioning with limited repair resources).

3. Maintainability: The user can obtain maintainability results through constructions of the SLAM networks.

4. Manpower: The model can be used to estimate manpower requirements by Air Force Specialty Code (AFSC).

SIMPLE_1

Model Category:	Simulation Environment
Point Of Contact:	Mr. Phil Cobbin, Sierra Simulations & Software
Telephone:	Commercial (800) 446-3697 Autovon N/A
Hosted On:	IBM PC, XT, AT, & True Compatible Microcomputers
Coded In:	SIMPLE_1

Model Applications: SIMPLE_1 is used primarily in the academic and civilian sectors; however, some manpower models have been developed for the U.S. Navy.

Verification: The user must assure that the model developed using SIMPLE_1 performs as intended. This may consist of peer code review and examination of the network logic. The verification plan must be included in the Test and Evaluation Master Plan (TEMP) for all models intended for use in OT&E.

Validation: SIMPLE_1 is a simulation environment; therefore, validation must be included in each model building process. The intended use of the SIMPLE_1 Model must examined in detail. The model is considered appropriate if it addresses the critical issues and the supporting Measures Of Effectiveness (MOEs), and if it is a realistic representation of the weapon system and its operational environment. Validation plans and previous validation efforts must be documented and referenced in the TEMP. The degree of confidence in the model varies with the quality of input data, modeling techniques, and the experiment design. Confidence in the SIMPLE_1 Model may be enhanced by comparison of the output results to test data, other models, or historical data.

Purpose: SIMPLE_1 provides the capability to develop simulation models as well as pre- and post-processors used to support the simulation project. In addition, the SIMPLE_1 environment permits the user to develop utility programs that may be used for such tasks as data collection or reduction. Once models are developed, the user may compile the model using the RUNSIM option. The model may then be re-hosted as a stand-alone executable system.

SIMPLE_1 provides an array of graphics utilities that permit the modeler to animate the simulation and present a BIT-mapped display via EGA or VGA output devices.

The model supports continuous as well as discrete event simulation capability. *SIMPLE_1* provides extensive statistics collection capability for events that occur during simulation. The user may declare variables and statistics requirements, perform file input/output operations, and animate the simulation results in real time.

The modeler may establish multiple run requirements or use SIMPLE_1 features to determine multiple run parameters based on the model behavior.

Discrete systems consist of networks that define the flow of events or entities within the model. Entities may be grouped and flow through the network while still retaining their unique attributes. In addition, dissimilar entities may be assembled to form a group. The entities flow through the blocks in the network and may represent objects such as tools, parts, and people.

Continuous models are constructed through the use of differential equations. An example of continuous model methodology is the change in thrust-to-weight ratio as a rocket consumes fuel following launch. SIMPLE_1 provides the capability to integrate discrete event simulation and continuous simulation through the use of built-in system functions.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY			1	1			1	
SUSTAINABILITY			2	2			2	
RELIABILITY								
MAINTAINABILITY			3	3			3	
PROVISIONING								
MANPOWER			4	4			4	

LEGEND: ▩ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Availability: The analyst may constrain resources and determine the impact on the weapon system's sortie rate.

2. Sustainability: The simulation also can be used to assess the ability of a unit to sustain operations, given constrained resources.

3. Maintainability: The user can obtain maintainability results through constructions of the SIMPLE_1 networks.

4. Manpower: The model can be used to estimate manpower requirements.

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SIMULATION MODELS

TRASANA Aircraft Reliability and Maintainability CAA Version II (TARMS II)

Model Category:	Simulation Model
Point Of Contact:	Dr. Dong Kim, U.S. Army, Concepts Analysis Agency
Hosted On:	VAX, Unisys
Coded In:	Simscript II.5

Telephone:	Commercial	(301) 295-2088	Autovon	295-2088

Model Applications: TARMS II has been applied to all Army aircraft, both fixed-wing and rotary wing.

Verification: TARMS II has undergone extensive reviews, including peer code reviews and desk checking, to ensure the model performs as intended. When used in OT&E, the verification process must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: TARMS II has not undergone a formal validation procedure. The model is presently undergoing extensive modifications, and will undergo formal validation procedures once modifications are completed.

Purpose: TARMS II is a stochastic, process-oriented, simulation model which represents the operation of any U.S. Army aviation organization, from company to theater in size. The model may simulate both peacetime and wartime scenarios, driven by a detailed list of mission requirements for the duration of the game. The Blue force is modeled as a set of aircraft of various types organized into company-sized elements, each element having its own maintenance personnel, test equipment, and stock of repair parts. The Red force is modeled as a mix of weapon systems, each representing a threat to the Blue force. While performing a mission, a mix of Blue aircraft may experience mechanical failures and combat damage that may result in a total loss of the aircraft, a forced landing in the field, an abort of the mission, or the generation of a required maintenance action. Combat may be two-sided, with both Red and Blue exchanging rounds. However, where a hit on Blue results in attrition or damage, the result of Blue engaging Red is either a miss or a kill. Some assumptions associated with TARMS II include the following: Ground vehicles used to transport contact teams do not experience failures or combat damage and are assumed to be available at all times; fuel and ammunition are assumed available at all times; each aviation organization may use only one aviation intermediate maintenance (AVIM) facility, thus the corps AVIM slice cannot explicitly be modeled at division level; recovery kits are assumed available at all times; cannibalization of aircraft destroyed in the field is not modeled; contact teams work on only one aircraft, and then return to base; each Blue aircraft is limited to one on-board weapon type; each hit of a Blue aircraft by a Red weapon is a unique event; and the cumulative effect of multiple hits is not modeled.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY			1					
SUSTAINABILITY			2					
RELIABILITY			3					
MAINTAINABILITY			4					
PROVISIONING								
MANPOWER			5					

LEGEND: ▩ = PRIMARY APPLICATION ▭ = SECONDARY APPLICATION

1. **Availability:** The user has the option of constraining resources to determine its effect on the availability of the system.

2. **Sustainability:** The model considers various levels of maintenance and may be used to analyze the ability of a unit to perform required missions, given equipment failures and the capability of supply to furnish replacement parts. The failed parts are modeled through the "back" repair shops and through depot-level repair.

3. **Reliability:** The user may input various reliability factors to determine the impact on the unit's ability to meet mission requirements.

4. **Maintainability:** The model may be used to analyze maintenance concepts such as deferrals, use of contact teams to fix forward, repair part order and ship time, and controlled substitution policies. The support system requirements, such as Military Occupational Speciality (MOS) staffing levels, quantity of test equipment, repair parts acquisition and stockage policies, number of "float" aircraft, and the number and location of aircraft for recovery and contact team missions also may be modeled.

5. **Manpower:** The model may be used to make initial determinations of manpower authorizations required to support a given scenario. The authorizations are by MOS, and are used for requirements estimates only.

Combat Analysis Sustainability Model (CASMO)

Model Category:	Simulation Model		
Point Of Contact:	Dr. Dong Kim, U.S. Army, Concepts Analysis Agency		
Telephone: Commercial	(301) 295-2088	Autovon	295-2088
Hosted On:	VAX, Unisys		
Coded In:	Simscript II.5		

Model Applications: The model currently is in development.

Verification: CASMO currently is undergoing extensive reviews, including peer code reviews and desk checking, to ensure the model performs as intended. When used in OT&E, the verification plan must be documented and included in the Test and Evaluation Master Plan.

Validation: A new model, CASMO currently is in the process of being delivered by the contractor and has not undergone formal validation. Once the complete model is delivered to the government, it will undergo a validation process.

Purpose: CASMO will rely on data produced by the Force Concepts Evaluation Model (FORCEM) and Vector-In-Commander (VIC) Model. The model will have preprocessors to perform the necessary data translation. It will model ground activity, but will be somewhat similar to TARMS II (see page A-22). Unit combat activity data are required by CASMO, FORCEM, and VIC to produce the combat scenario driver. CASMO uses preprocessors to perform the necessary conversion on the outputs of FORCEM and VIC. The user must manually gather and enter data (e.g., organizational structure and the number of each type weapon system). Functionally, CASMO will model attrition, movement, Command, Control, and Communications, and logistics for ground forces. The scenario preprocessor decomposes the combat model unit (division for FORCEM or battalion for VIC) into company-sized combat arms units (armor, infantry, artillery) and positions the company-sized units, according to doctrine, within the division area. The company-sized unit is assigned its authorized quantity of weapon systems. The preprocessor also positions division-level maintenance and supply organizations within the division area.

CASMO uses shotline data contained in Sustainability Predictions for Army spare components Requirements for Combat (SPARC) similar to the TARMS II procedure. These data predict the specific damage expected from each hit of an enemy weapon. Shotline data are produced by the Ballistics Research Laboratory (BRL). CASMO uses the preprocessor from TARMS II to process shotline data for its use. As with TARMS II, the shotline preprocessor produces a series of files, one for each Red-on-Blue, killer-victim combination. Each file contains a random selection of several thousand shotlines; each shotline contains data pertaining to a hit at a specific location and aspect angle. The data also contain the list of parts, and the probability that that part is damaged. In addition, the resources required to repair or replace the component (damage repair) are contained in the file.

CASMO deterministically computes scheduled maintenance for each weapon system within each unit. Unscheduled maintenance is determined stochastically for each type of weapon system. The model also determines the expected number of failures resulting from the specified aging and the user-input system failure rates. For each failure, a specific part is randomly selected, based on the user-input relative part-failure rate. A specific maintenance action (e.g., remove and replace) is then selected, based on the probabilities specified by the user. Combat damage also is modeled, using scenario specified hit data. CASMO selects a shotline, which gives the probability of each part being hit. The model stochastically selects the parts hit, and then sets the corresponding maintenance actions in a manner that is analogous to unscheduled maintenance.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY		1						
SUSTAINABILITY		2						
RELIABILITY		3						
MAINTAINABILITY		4						
PROVISIONING		5						
MANPOWER		6						

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. **Availability:** The analyst can constrain various resources to determine the impact on weapon system availability.

2. **Sustainability:** CASMO is an event-step simulation model for the operation of the logistics support base within Army divisions. It emphasizes the sustainability of major ground-based weapons systems in an operational environment and assesses the ability of major weapon systems to meet mission requirements. It also provides data on the division-level supply and maintenance organization and policy to determine their effect on weapon system performance.

3. **Reliability:** The model allows the examination of weapon system failure characteristics. The system failure rate is given in hours, rounds fired, and miles. The user inputs the relative frequency of component failure and the implied assignment of parts to one of the three subsystems (mobility, firepower, other). The user also specifies the system redundancy, thus adjusting the probability of parts failure and the probability of the resulting maintenance action.

4. **Maintainability:** The model can be used to compute scheduled maintenance and determine unscheduled maintenance and combat damage.

5. **Provisioning:** Repair parts assets can be evaluated with the user establishing the manner in which repair parts inventory is modeled. Method 1 establishes an authorized quantity at each type maintenance unit. Method 2 assigns a probability of fill at each type maintenance unit.

6. **Manpower:** The model may be used to make an initial determination of manpower authorizations, consisting of quantities and skill levels, required to support a given scenario.

Logistics Composite Model (LCOM)

Model Category:	Simulation Model
Point Of Contact:	Lt. Col. Kunkle, AFOTEC/LG4*

Telephone:	Commercial	(505) 844-0348	Autovon	246-0348

Hosted On:	Honeywell, CDC, IBM, CRAY, VAX
Coded In:	Simscript 11.5, FORTRAN, COBOL (Pre/Post Processors)

Model Applications: The model has been used in the B-1B, F-15, F-16, F-20, F/EF-111A/D, and E-3A programs.

Verification: LCOM has undergone extensive reviews, including peer code reviews and desk checking, to ensure the model performs as intended. When used in OT&E, the verification efforts must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: Initial validation took place at Seymour-Johnson AFB, SC. This test involved the deployment of a squadron of F-4 aircraft to a remote section of the ramp, and all resources were constrained to levels used within the LCOM simulation. The deployed aircraft used the same flying scenario as that which was used in the simulation. The simulation projections matched almost exactly the performance demonstrated by the deployed aircraft. In more recent examples, AFOTEC has validated the model by comparing results with field data from comparable systems. This technique was used to validate F-15 and F-16 simulation models.

Purpose: To obtain the necessary versatility of being able to apply LCOM to a wide range of weapon systems, the majority of the simulation logic is provided externally in data rather than as part of the software itself. Users provide data in the form of networks that represent the system being modeled. These externally provided data constitute roughly 75% of the decision logic.

During the simulation process, when a mission is requested an attempt is made to complete it by obtaining the needed aircraft from a ready pool and beginning their processing through a set of user-defined pre-sortie tasks. A take-off and cancellation time also is established by the mission request. Once the required aircraft complete the set of pre-sortie tasks and the take-off time is reached, they begin the sortie task (fly the sortie). Upon completion of this task, they must undergo the defined post-sortie task. When completed, the aircraft are returned to the serviceable pool. The time to cancel will be utilized only if insufficient aircraft are ready to fly the mission, or if the pre-sortie task cannot be completed in the allotted time.

The pre-sortie and post-sortie blocks are user-supplied logic networks that represent sections of logic for the main module to process. Pre-sortie networks could include tasks such as preflight checks and weapons loading. Post-sortie tasks might include fuel service, post-flight inspection, unscheduled and scheduled maintenance, etc. Tasks within these networks will define the resources required to do the task priority of work relative to other defined maintenance and their relationship to succeeding tasks. The details of the task networks are user controlled and limited only by the availability of data and the computer memory required to process the task networks.

*NOTE: Questions on uses of LCOM, beyond those at AFOTEC, should be directed to Msgt. Allan Bishop, (512) 652-2833.

The main module of the LCOM software is designed to simulate a broad range of aircraft operations, scheduling, maintenance, and supply functions at an Air Force Base. In accordance with the LCOM design objectives, the logical ordering of actions within the simulation may be adapted to many problem situations and therefore must be specified by the user for his specific application. The user is free to define both the resources of interest and the manner of their intended utilization, while the software provides the necessary controls and structure to simulate and maintain a record of their action and interaction.

Operations data include the number of missions, mission type, time of take-off, sortie duration, number of aircraft required, and other related mission data. Included in the data are the activities and user-defined external requirements for either aircraft or non-aircraft resources that are to be processed in such a manner that does not lead to or involve a sortie task. Maintenance data utilized are primarily AFM 66-1/AFM 66-5 data in a form of a maintenance network. These data include necessary scheduled maintenance actions required on both aircraft and non-aircraft resources. Supply data include supply demand and resupply processes at the various levels of part indentures, i.e., assembly, sub-assembly, sub-sub-assembly, module, etc., according to the user definition. Generally, Work Unit Code references are used.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY			1		1	1	1	
SUSTAINABILITY			2		2	2	2	
RELIABILITY								
MAINTAINABILITY			3		3	3	3	
PROVISIONING			4					
MANPOWER			5		5			

LEGEND: ▓ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Availability: The model can be used effectively to determine availability of aircraft or other resources during simulation experiments.

2. Sustainability: Sustainability assessments may be produced using LCOM. Spares or other resources can be constrained, and the associated effect on the ability of the unit to fly the required number of sorties can be examined.

3. Maintainability: The model's flexible network architecture provides the ability to perform maintainability analysis at whatever maintenance level is appropriate.

4. Provisioning: LCOM could be used for determination of parts requirements, but traditionally this function has been handled by other Air Force models (i.e., DYNA-METRIC).

5. Manpower: One of the primary uses for LCOM within the Air Force is the determination of aircraft maintenance manpower requirements. This methodology has been very successful, and its use in this application has been validated and accepted.

TIGER

Model Category:	Simulation Model
Point Of Contact:	Mr. Palmer Luetjen, NAVSEA, SEA05MR
Telephone:	Commercial (202) 692-2150 Autovon 222-2150
Hosted On:	Various computer systems
Coded In:	FORTRAN

Model Applications: Applications of the TIGER Model include every ship in the inventory.

Verification: TIGER has undergone extensive reviews, including peer code reviews and desk checking, to ensure the model performs as intended. When used in OT&E, the verification efforts must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: One of the initial validation efforts took place during builders' trials at Puget Sound in 1970. TIGER was used to predict the reliability of the Patrol Hydrofoil (PHM) and the results were compared to the reliability measured during the trials. Cases where the predicted reliability failed to match the actual reliability were traced to errors in data entry or data reporting. Both the contractor (Boeing) and NAVSEA participated in the validation effort. Prior to using TIGER on any new system, the mission profile must be approved to assure it is representative of the intended profile. A deterministic model, REX, is used to predict the reliability for one or more of the less complex subsystems. Manual calculations also may be accomplished using Markov Chain theory. TIGER then is used to predict reliability for the same subsystem. The results are compared to ensure TIGER is providing reasonable reliability estimates for the particular system.

Purpose: TIGER is an event-driven, stochastic simulation model. It can predict the reliability, maintainability, and availability for all systems, ranging from the smallest subcomponent to total ship or fleet of ships. It is a large and versatile simulation model, especially created for the study of the Reliability, Maintainability, and Availability (RMA) characteristics of systems. The model can accept data from standard databases (i.e., Navy 3M Database). Standard TIGER input information consists of mission, equipment, and system configurations.

The user must input the weapon system objectives and functional requirements. This starts with the mission profile, which contains a full description of mission objectives as well as the system and equipment functions required to achieve these objectives. During the mission profile development and throughout the system and equipment design process, more detailed information must be derived to support the engineering analyses that are part of the application of TIGER. The mission profile data must be translated into a timeline format acceptable to the TIGER computer program. The level of detail provided to the TIGER model by the timelines is determined by the extent of information provided in the engagement database.

Reliability Block Diagram methodology represents the breakdown of the hardware system being analyzed into its major items and the interfaces among these items. Each block may represent either an equipment function or a hardware element. The next step in equipment definition is to establish the equipment parameters. These factors are quantitative measurements for the Reliability and Maintainability (R&M) and the duty cycle of each equipment.

The user must clearly specify all system operating rules. This set of data describes the effects of equipment failures on system and mission success, considering the capabilities of the system to repair equipment failures. This description also must discuss the maintenance and spares support policy. TIGER also can represent the spares support stocking, issuing, and reordering of spares. The model is flexible and will either allow unlimited spares, or apply spares constraints.

The internal model operation can have one of three internal equipment events: failure of an equipment, arrival of a spare for awaiting equipment, or repair of an equipment. When TIGER initiates a mission, all equipment items are in good condition and full logistic support is available. The user has the ability to alter the initial conditions by calling special preprocessors that track and accumulate usage time, along with the associated failures and spares consumption.

TIGER reports the results of the simulation in terms of system and equipment indexes. These estimators of system performance include system RMA, measures of system activity during the mission, estimates of long term stable system characteristics, standard deviation, equipment performance statistics, and critical equipment assessment. The primary figures of merit are reliability, instantaneous availability, critical equipment lists, and average availability. A secondary purpose of TIGER is to provide sensitivity analysis on systems under evaluation.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY	1					1		
SUSTAINABILITY	2					2		
RELIABILITY	3					3		
MAINTAINABILITY	4							
PROVISIONING								
MANPOWER								

LEGEND: ▒ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. Availability: An index of performance calculated by TIGER is instantaneous availability. It is defined as the probability that the system will be "up" (be capable of operating satisfactorily) at a stated time. The instantaneous availability is calculated at the beginning and end of each phase. TIGER also calculates average availability, i.e., the probability that a system is up and capable of satisfactory operation at any (random) point in the timeline.

2. Sustainability: This model can determine the ability to sustain an engagement, given equipment failures and spares replacement.

3. Reliability: An advantage of TIGER over similar "mission reliability models" (MIL-STD-756B) is that the TIGER format allows direct utilization of the basic building blocks of reliability engineering, the Reliability Block Diagram (RBD).

4. Maintainability: This model provides estimators of system performance, including system maintainability measures, during the mission.

Comprehensive Aircraft Support Effectiveness Evaluation (CASEE)

Model Category:	Simulation Model			
Point Of Contact:	Mr. Andy Darby, NAVAIR, Air 04			
Telephone:	Commercial	(202) 692-5661	Autovon	222-5661
Hosted On:	IBM 3090			
Coded In:	GPSS/Norden			

Model Applications: The model has been applied to virtually all naval tactical aircraft, including helicopters and anti-submarine aircraft.

Verification: CASEE has undergone extensive reviews, including peer code reviews and desk checking, to ensure the model performs as intended. When used in OT&E, the verification efforts must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: An example of CASEE validation took place in 1985, during the first carrier deployment of the F-18 aircraft. The test involved two squadrons of F-18 aircraft (20 aircraft) involved in a standard Navy carrier operational scenario. The test was conducted by members of the F-18 Assistant Program Manager for Logistics (APML) program office and a support contractor, Information Spectrum, Inc. Predictions derived from CASEE were compared with F-18 operational data available in the 3M database. Predictions for both Reliability and Maintainability (R&M) and readiness were good, and the test was considered successful. Since the 1985 test, the model has undergone several further validation tests involving the comparison of model predictions to actual operational data for carrier-based aircraft.

Purpose: Model application traditionally starts early in the acquisition process (at or prior to Milestone 0). CASEE is used primarily for aircraft operations simulation. The aircraft can be ship- or shore-based and may be fixed- or rotary wing. The enhancements include preprocessors that simplify data acquisition, drawing data from LSAR and 3M databases and converting them into a format acceptable to CASEE. Postprocessors provide decision support tools and enhanced model output, to include graphs and detailed day-by-day reports.

CASEE has been linked to the REPAIRS Model that provides assessment of the depot repair actions and spares pipeline flow. Prior to interface with REPAIRS, depot and pipeline delays were calculated as a wait time. This procedure was less than accurate, because pipeline delays are dynamic and do not demonstrate a linear relationship. The addition of the depot model has provided an additional resolution of detail for the analyst.

CASEE uses an aggregate approach to look at individual work centers. It looks at work backlog by work center rather than by individual maintenance task.

The analyst has the ability to use simulation at Milestone 0 to perform suitability analysis. Once requirements are specified, CASEE can be used to simulate the system to determine its ability to perform satisfactorily. This early analysis may depend on comparability analysis techniques

when system data are not available. Such early assessment can predict availability, given R&M factors for various components.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY			1					
SUSTAINABILITY			2					
RELIABILITY			3					
MAINTAINABILITY			4					
PROVISIONING								
MANPOWER			5					

LEGEND: ▩ = PRIMARY APPLICATION ☐ = SECONDARY APPLICATION

1. **Availability:** This model determines an aircraft's ability to meet mission requirements by examination of the complete aircraft system and aircraft multiple missions. It also may be used to determine availability in terms of essential equipment or systems. It develops a ratio of "mission-capable" to "total time."

2. **Sustainability:** This model determines mission capability, a key measure, and provides inputs for readiness and resources studies. It also generates realistic cost factors for evaluation, aids in defining military capability, and considers battle damage and attrition.

3. **Reliability:** The model can be used to determine the impact of improvements in reliability in terms of availability and manpower savings.

4. **Maintainability:** Information on maintenance tasks, maintenance manpower, and queues are generated by this model.

5. **Manpower:** Output reports may be analyzed to determine manpower requirements to meet objectives in a given scenario. This model also provides data on the maintenance manpower utilization.

Comprehensive Operational Support Evaluation Model for Space (COSEMS)

Model Category:	Simulation Model
Point Of Contact:	Mr. Ron Janz, Advanced Technology, Inc.
Telephone:	Commercial (213) 640-1050 Autovon N/A
Hosted On:	VAX/VMS
Coded In:	Ada

Model Applications: The COSEMS is being applied to the Strategic Defense System (SDS) satellites and satellite constellations.

Verification: COSEMS has undergone extensive reviews including peer code reviews, as well as unit, integration and production level testing to ensure the model performs as intended. The model also was tested by an outside independent consultant, and the independent derivation of the algorithms was verified by another contractor. When used in OT&E, the verification efforts must be documented and referenced in the Test and Evaluation Master Plan (TEMP).

Validation: COSEMS has not undergone validation as defined in 3.1.5 (see page 3-2). This simulation environment is designed to model space systems that are presently in the concept definition phase; therefore, comparison of predictions to actual system performance has not been possible. When these systems (specifically, the space station) become functional, the model will undergo formal validation.

Purpose: The COSEMS Model has been developed to investigate the support alternatives for satellites and satellite constellations. The current approach for maintaining satellite availability is to replace entire satellites when they fail, either by launching a replacement satellite or activating an in-orbit spare. Efforts to reduce the costs to support satellites in large constellations, such as those proposed for the Strategic Defense System, has led to the consideration of alternative support concepts such as those based on in-orbit support. This calls for building satellites with standardized modules -- orbital replacement units or (ORUs) -- that can be replaced in orbit using tele-robotic devices attached to an orbital maneuvering vehicle (OMV). To evaluate these support concepts, COSEMS, a large-scale simulation of ground and space operations, has been developed. The model simulates the complex dynamic interactions among the elements of the SDS, its support system, and the expendable launch delivery system. The model is of sufficient detail to provide realistic quantitative assessment of in-orbit support alternatives relative to the approach of unit satellite replacement. The model permits the prediction of (a) constellation/ring/payload availability versus time, (b) the impact of system reliability, maintainability, and supportability on availability, and (c) the development of initial conditions for other modeling and simulation efforts, including wargaming and engagement models.

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY				1				
SUSTAINABILITY				2				
RELIABILITY				3				
MAINTAINABILITY				4				
PROVISIONING				5				
MANPOWER								

LEGEND: ▩ = PRIMARY APPLICATION ▭ = SECONDARY APPLICATION

1. **Availability:** Operational availability of the satellite constellation, orbital ring, and payload are primary outputs of the model. User-specified minimum operational availability data are used as inputs to the decision to implement the primary or backup response, when this is applicable.

2. **Sustainability:** The ability of a satellite constellation to perform its intended mission may be analyzed, given hardware failures, consumable depletion events, delays in transporting satellites, ORUs, consumables and other equipment into space, and delays in performing unmanned maintenance and service in space.

3. **Reliability:** System block diagrams, level of redundancy in each subsystem, and shape and scale parameters in Weibull models of each satellite module are developed by the user (during an interactive session with the preprocessor).

4. **Maintainability:** The user may analyze maintainability considering support concept, support system architecture, constellation architecture, spacecraft design (extent of replaceable modules, module replacement time), and other in-orbit operations times (e.g., OMV payload integration time).

5. **Provisioning:** The model predicts the annual number of ORUs that will be required to maintain a satellite constellation through its life cycle.

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SURVEY SUMMARY

SURVEY SUMMARY

Model Category:	All Categories		
Point Of Contact:	See Respective Individual Listing		
Telephone: Commercial	Ref. Above	Autovon	Ref. Above
Hosted On:	See Respective Individual Listing		
Coded In:	See Respective Individual Listing		

Summary: The automated systems, simulation environments, and simulation models included in this document are summarized on the following page. The name and associated number for each model or system reviewed and the page number that contains the detailed description of the model are listed below. A summary of the suitability attributes of the models (1 - 12) are shown in the figures on the facing page. The top figure represents the primary model or system applications; the bottom figure represents the secondary, or potential, areas of application. These figures may be used to determine the appropriate model or system for a particular application. By referring to the page number of the selected model (see listing below), the reader can obtain a more detailed description of the model or system. The spreadsheet (see automated systems, item 3 below) was considered so generic that the utility of presenting it in the summary chart was negligible. If a model or system is not available for a particular function, and calculations are required during the analysis, the use of a spreadsheet should be considered.

The subsections within this Appendix consist of the following:

Application To Operational Suitability

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY	10	8	5,6,7, 8,11	4,12				
SUSTAINABILITY	10	8	5,6,7, 8,11	12				
RELIABILITY	10	8	2,7, 11	4,12				
MAINTAINABILITY	10	8	5,6,7, 8,11	4,12				
PROVISIONING		8	1,9	12				
MANPOWER		8	5,6,7, 8,11					

LEGEND: ▒ = PRIMARY APPLICATION

Figure A-1. SUMMARY OF PRIMARY OBJECTIVES

MODEL OBJECTIVES	SHIPS	LAND VEH	AIR VEH	SPACE	FIELD EQUIP	C&C	MISSILES	AIR DEF
AVAILABILITY				5,6	9	9,10	5,6,9	
SUSTAINABILITY				5,6	9	9,10	5,6,9	
RELIABILITY						10		
MAINTAINABILITY				5,6	9	9	5,6,9	
PROVISIONING					1			
MANPOWER				5,6	9		5, 6	

LEGEND: ▭ = SECONDARY APPLICATION

Figure A-2. SUMMARY OF SECONDARY OBJECTIVES

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